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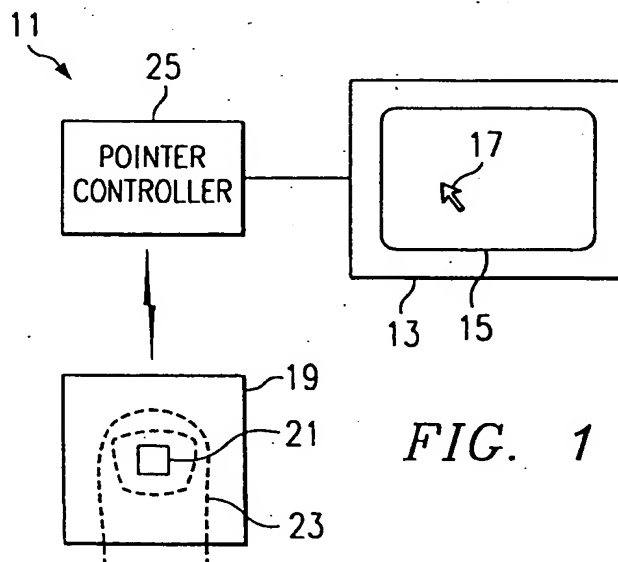
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(54) **Capacitive semiconductor user input device**

(57) A method of and system for providing user input to a computer, or the like, having a display by detecting a change in fingerprint pattern of a user. The system controls the position of a pointer on a display by detecting motion of ridges and pores of a fingerprint of a user

and moving the pointer on the display according to detected motion of the ridges and pores of the fingerprint. The system captures successive images of the fingerprint ridges and pores and detects motion of the ridges and pores based upon the captured successive images.



*FIG. 1*

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## Description

[0001] The present invention relates generally to methods of and systems for providing user input to user interfaces for computers and the like, and more particularly to a semiconductor capacitive user input device and method for controlling the position of a cursor or pointer on a display.

[0002] Pointing devices are commonly used in conjunction with computers to control the movement of graphical cursors on a display screen and to select objects and operate controls displayed on the screen. For desktop computers and workstations, the most commonly used pointing device is a mouse. As is well known, a mouse is moved over a flat surface to control the position of the pointer on the display screen. A mouse includes one or more buttons that may be pressed or clicked to perform operations on objects and controls displayed on the screen.

[0003] Recently, small laptop and notebook computers have become very popular. Laptop and notebook computers may be used in conjunction with a docking station so that a standard keyboard, mouse, and CRT display may be used for the user interface. However, laptop and notebook computers are designed to be used while traveling and away from the office or home. In such remote locations, the user does not always have available a flat surface upon which to use a mouse. Accordingly, laptop and notebook computers typically have a built-in pointing device, such as a track ball, touch pad or a pressure-actuated pointing device, such as the IBM TrackPoint (TM) device.

[0004] In addition to computers, certain television and set top box systems include a graphical user interface for enabling a user to input information to the system and change or control system settings. The user input device for such systems is typically a hand-held infrared keypad controller. Such controllers may include devices similar to those used in laptop and notebook computers to control the position of a pointer on the television screen.

[0005] Track balls, touch pads, and pressure-actuated pointing devices have certain drawbacks. For example, while track balls are compact, they require considerable finger movement to produce large cursor displacements at low velocities. In addition, track balls are mechanical devices that may not be well suited for operation in dirty environments. A touch pad comprises a rectangular surface that is mapped to correspond to a display screen. By touching a location on the touch pad, the user causes the computer to move the pointer to the corresponding location on the screen. Since a typical touch pad is substantially smaller than the screen, accurate positioning of the pointer can be difficult. In order to be usable, a touch pad must be large enough to permit the user to position the pointer accurately. The large size of touch pads makes them difficult or impossible to use in a hand held device such as a television remote con-

trol.

[0006] Pressure-actuated pointing devices include strain gages or transducers that detect the direction and magnitude of the force of a user's finger on the device.

The pointer is moved in a direction corresponding to the direction of the force and at a speed corresponding to the magnitude of the force. Certain individuals have trouble using pressure-actuated pointing devices to position the pointer accurately on the screen. One source of trouble is inertia, whereby the pointer continues to move after the user releases the pressure on the device.

[0007] It is an object of the present invention to provide a low-cost, small-sized, non-mechanical pointer position controlling device that overcomes the shortcomings of the prior art.

[0008] The present invention provides a method of and system for providing user input to a computer, or the like, having a display by detecting a change in fingerprint pattern of a user. In one of its aspects, the present invention provides a method of and system for controlling the X-Y position of a pointer on a display by detecting motion of ridges and pores of a fingerprint of a user and moving the pointer on the display according to detected motion of the ridges and pores of the fingerprint. In another of its aspects, the present invention provides Z axis input, such as button clicks, by detecting a widening of fingerprint ridges caused by increased pressure on a detector surface, or by detecting the lifting or the placement of the finger from or on the detector surface.

[0009] The method and system of the present invention captures successive images of the fingerprint ridges and pores and detects motion in or changes of the ridges and pores based upon the captured successive images.

The method and system of the present invention captures the successive images by scanning an array of sensors, each of the sensors being smaller than the width of an individual ridge of a fingerprint. Preferably, the array of sensors is smaller than the pad of a finger of a user. In the preferred embodiment, each sensor of the array of sensors includes a capacitive element and the system captures the successive images by detecting changes in capacitance of the capacitive elements.

[0010] Some embodiments of the invention will now be described by way of example and with reference to the accompanying drawings in which:

[0011] Figure 1 is a block diagram of a system according to the present invention.

[0012] Figure 2 is a block diagram of a sensor array according to the present invention.

[0013] Figure 3 illustrates the physical structure of the individual sensor cells and their electrical operation according to the present invention.

[0014] Figures 4A and 4B comprise a pictorial illustration of the operation of a system according to the present invention to control the X-Y position of a pointer.

[0015] Figures 5 is a pictorial illustration of the operation of a system according to one embodiment of the

present invention to control the Z position of a pointer.

**[0016]** Figures 6 is a pictorial illustration of the operation of a system according to an alternative embodiment of the present invention to control the Z position of a pointer.

**[0017]** Referring now to the drawings, and first to Figure 1, a system according to the present invention is designated generally by the numeral 11. System 11 includes a display 13, which includes a screen 15. A pointer 17 is shown displayed on screen 15. System 11 includes a pointer controller 25 that controls the position of pointer 17 on screen 15. Display 13 may be, for example, a standard CRT computer monitor or television. Alternatively, screen 13 may operate on any of several non-CRT technologies used in laptop and notebook computers.

**[0018]** System 11 includes a user input device 19. In Figure 1, user input device is represented generally as a rectangle. The specific form of user input device 19 is determined by the configuration. For example, user input device may be integrated into the body of a laptop or notebook computer, or it may be part of a hand held infrared remote control device.

**[0019]** User input device 19 includes a sensing element 21. As will be described in detail hereinafter, sensing element 21 senses movement of a user's thumb or finger, shown in phantom and designated by the numeral 23, to control the X-Y position of pointer 17 on screen 15. Sensing element 21 may also sense changes of finger pressure on sensing element, by detecting changes in width of fingerprint ridges, or the placing or lifting of the finger on sensing element 21, to control the Z position of pointer 17 or to input button inputs to processor. As shown in Figure 1, sensing element 21 is substantially smaller than the pad portion of finger 23.

**[0020]** The direction and speed of movement of the finger 23 over sensing element 21 is output to a pointer controller 25. Pointer controller 25 receives output from user input device 19, preferably as X-Y and Z position changes, and produces an output to control the position of pointer 17 on screen 15.

**[0021]** Referring now to Figure 2, there is shown a block diagram of user input device 19. User input device 19 is preferably integrated into a single chip, and it includes an array 27 of cells 29. For purposes of illustration, array 27 is shown comprising nine cells 29. In an actual device, more than nine cells would be included. Each cell 29 is smaller than the width of a fingerprint ridge and enough cells 29 are included in array 27 so that several ridges and pores may be detected. In the preferred embodiment, cells 29 are on a pitch of 50 $\mu$ m, which corresponds to a resolution of about 508 dpi.

**[0022]** Device 19 includes a horizontal scanning stage 31 and a vertical scanning stage 33. Scanning stages 31 and 33 enable one cell 29 at the time according to a predetermined scanning pattern. In the preferred embodiment, each cell 29 is scanned once each millisecond to produce a frame rate of 1,000 frames per

second.

**[0023]** Input device 19 includes a power supply and scan control unit 35. Power supply and scan control unit 35 supplies a reference voltage to each cell 29 of array 27. Power supply and scan control 35 also operate scanning stages 31 and 33 to produce the desired scanning of cells 29.

**[0024]** An A/D converter 37 is connected to receive the output of each cell 29 of array 27. The output of A/D converter 37 is connected to output logic 39. Output logic 39 processes the output of buffer 37 to capture successive images of a portion of the fingerprint of the user. Output logic 39 compares successive images to detect movement of the fingerprint. If output logic 39 detects movement, output logic 39 computes the displacement of the fingerprint ridges and pores in the X and Y directions over the scanning period, which in the preferred embodiment is one millisecond, and outputs X and Y displacement signals to pointer controller 25 of Figure 1. If output logic 39 detects a widening or flattening of the fingerprint ridges, which indicates an increase in pressure of the user's finger, or the lifting of the finger from sensing element 21, output logic 39 outputs a Z displacement signal, which pointer controller 25 may interpret as a button press or click.

**[0025]** Array 27 must be a sufficient size to capture a partial image containing several fingerprint ridges and pores. As the finger is moved over array 27, user input device 19 detects, either directly or indirectly, the relative motion of the finger surface. In direct detection, user input device 19 contains motion-detection circuitry that allows it to output directly the relative motion direction and speed of the finger surface. In indirect detection, relative motion between frames is calculated explicitly with a simple correlation algorithm running in a standard digital controller. The higher the frame rates supported by user input device 19, the less motion there will be between frames, even at maximum finger motion speeds, and the easier the task of the correlation algorithm for computing relative motion. At a frame rate of 1,000 frames per second, acceptable results can be achieved using a square array of sensors about five millimeters on a side.

**[0026]** Referring now to Figure 3, there is illustrated the structure and operation of a cell 29 according to the present invention. The preferred cell of the present invention is of the type disclosed in Tartagni, U.S. Patent Application Serial No. 08/799,543, filed February 13, 1997, entitled Capacitive Distance Sensor, the disclosure of which is incorporated herein by reference. Each cell 29 includes a first conductor plate 47 and a second conductor plate 49 supported on a semiconductor substrate, which is preferably a conventional silicon substrate that may have a conventional shallow epitaxial layer defining an upper surface region thereof. The top surface of the substrate includes an insulating layer 41. Insulating layer 41 is preferably an oxide layer, which may be a conventional thermally grown silicon dioxide

layer. Conductor plates 47 and 49 are covered by a protective coating 51 of a hard material. Protective coating 51 protects sensor 29 from abrasion, contamination, and electrostatic discharge.

**[0027]** Each cell 29 includes a high gain inverting amplifier 53. The input of inverter 53 is connected to a reference voltage source  $V_{REF}$  through an input capacitor 54. The output of inverter 53 is connected to an output  $V_{OUT}$ . The input of inverter 53 is also connected to conductor plate 47 and the output of inverter 53 is also connected to conductor plate 49, thereby creating a charge integrator whose feedback capacitance is the effective capacitance between conductor plates 47 and 49.

**[0028]** When a finger 23 is placed on the surface of protective layer 51, the surface of the skin over each sensor acts as a third capacitor plate separated from adjacent conductor plates 47 and 49 by a dielectric layer that includes protective coating 51 and a variable thickness of air. Because fingerprint valleys or pores will be farther from conductor plates 47 and 49 than finger ridges 57, sensors 29 beneath valleys or pores will have more distance between their conductor plates 47 and 49 and the skin surface than sensors under ridges. The thickness of this dielectric layer will modulate the capacitance coupling between plates 47 and 49 of each cell 29. Accordingly, sensors 29 under valleys or pores will exhibit a different effective capacitance than sensors 29 under ridges. As shown in Figure 3, the effective capacitance of sensor 29a is different from the effective capacitance of sensor 29b.

**[0029]** Sensors 29 work in two phases. During the first phase, the charge integrator is reset with a switch 59 by shorting the input and output of inverter 53. This causes inverter 53 to settle at its logical threshold. During the second phase a fixed charge is input to charge integrator, causing an output voltage swing inversely proportional to the feedback capacitance, which is the effective capacitance between conductor plates 47 and 49. For a fixed amount of input charge, the output of inverter 53 will range between two extremes depending on the effective feedback capacitance value. The first extreme is a saturated voltage level if the effective feedback capacitance is very small. The second extreme is a voltage close to the logical threshold, which is the reset value, when the effective feedback capacitance is large. Since the distance between the skin and the sensor changes the effective feedback capacitance of the charge integrator, the output of sensor 29a under ridge 57 will be different from the output of sensor 29b under valley 55.

**[0030]** The operation of the system of the present invention to control the X-Y position of pointer 17 on screen 15 is illustrated with respect to Figures 4A and 4B, which illustrate the movement of pointer 17 on screen 15 responsive to successive captured images of a portion of a user's fingerprint. In Figure 4A, an image of a portion of a user's fingerprint is captured by sensing element 21 at an initial time  $T_0$  is represented by the numeral 61. In Figure 4B, pointer 17 is positioned at an

initial position at time  $T_0$ . As the finger is moved over sensing element 21, output logic 39 of Figure 2 detects a change in position of the dark ridges and/or pores, which are light areas within the dark ridges, and computes displacement the X and Y directions of the ridges or pores over the scanning period and outputs X and Y displacement signals to move pointer 17, as indicated by arrows in Figure 4B. For example, image 62 of Figure 4A captured at time  $T_1$  shows the ridges and pores displaced a distance  $X_1$  in the X direction and a distance 0 in the Y direction. Correspondingly, pointer 17 moves to the right in Figure 4B. Similarly, image 63 of Figure 4A shows the image of the ridges and pores captured at a later time  $T_2$ , wherein the image is displaced a distance  $X_2$  in the X direction and a distance 0 in the Y direction. The further movement of the finger causes a corresponding further movement of pointer 17 in the direction of the right arrow of Figure 4B.

**[0031]** As another example, image 64 of Figure 4A captured at time  $T_1$  shows the ridges and pores displaced a distance  $X_1$  in the X direction and a distance  $Y_1$  in the Y direction. Correspondingly, pointer 17 moves up and to the right on screen 15 in Figure 4B. Similarly, image 65 of Figure 4A shows the image of the ridges and pores captured at a later time  $T_2$ , wherein the image is displaced a distance  $X_2$  in the X direction and a distance  $Y_2$  in the Y direction. The further movement of the finger causes a corresponding further movement of pointer 17 in the direction of the up and right diagonal arrow of Figure 4B.

**[0032]** It will be recognized that the present invention detects motion of the finger in all X-Y directions, as shown by the remaining images of Figure 4A, and that such detected motion causes corresponding movement of pointer 17, as indicated by the arrows of Figure 4B. Those skilled in the art will recognize that motion in all directions, and not just the forty-five degree directions in the examples of Figures 4A and 4B, may be detected. The high resolution provided by the detector of the present invention enables the motion of pores to be detected. The ability to detect pores makes it possible to detect motion in a direction generally parallel to the ridges.

**[0033]** The operation of the system of the present invention to control the Z position of pointer 17 on screen 15 or to perform button clicks is illustrated with respect to Figures 5 and 6, which illustrate the change in width of fingerprint ridges responsive increased pressure of a user's finger on sensing element 21. In Figure 5, an image of a portion of a user's fingerprint is captured by sensing element 21 at a time  $T_0$ . Image 71 shows narrow ridges, which indicates a light touch on sensing element 21. An image 72 of the user's fingerprint captured by sensing element 21 at a later time  $T_1$  shows the ridges and pores is not displaced, but the ridges are wider than those of image 71. Similarly, an image 73 of the user's fingerprint captured by sensing element 21 at a still later time  $T_2$  shows the ridges and pores again not

displaced, but the ridges are even wider than those of image 72. Images 72 and 73 indicate an increase in finger pressure on sensing element 21. Similarly, images 74 and 75, which are captured at later times  $T_3$  and  $T_4$ , respectively, indicate a decrease in finger pressure on sensing element 21. If the system senses the widened and narrowing of the ridges within a predetermined time period, i.e.  $T_4$  minus  $T_0$  is less than a preselected value, the system outputs a mouse button click, which is interpreted in the manner well known to those skilled in the art to make user selections and the like.

[0034] In Figure 6 there is shown an alternative embodiment of the Z control of the present invention. An image 77 of a portion of a user's fingerprint is captured by sensing element 21 at a time  $T_0$ . Image 77 shows fairly wide ridges, which indicates a medium touch on sensing element 21. An image 78 of the user's fingerprint captured by sensing element 21 at a later time  $T_1$  shows the ridges and pores is not displaced, but the ridges are narrower than those of image 77, which indicates a lessening of finger pressure on sensing element 21. An image 79, captured by sensing element 21 at a still later time  $T_2$  is blank, which indicates that the user's finger has been lifted from sensing element 21. Images 80 and 81, which are captured at later times  $T_3$  and  $T_4$ , respectively, indicate a return of the user's finger pressure on sensing element 21. If the system senses the lifting and return of the ridges within a predetermined time period, i.e.  $T_4$  minus  $T_0$  is less than a preselected value, the system outputs a mouse button click.

[0035] From the foregoing, it may be seen that the present invention is well adapted to overcome the shortcomings of the prior art. The pointer position control device of the present invention is non-mechanical and, therefore, not subject to breakage or mechanical failure. The device of the present invention is small in size, and it may be fabricated on a single integrated circuit chip. The device's small size makes its cost very low compared to devices of the prior art.

[0036] Although the present invention has been illustrated and described with respect to a presently preferred embodiment, it is to be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

## Claims

1. A method of providing user input to a computer system including a display, which comprises the steps of:

detecting a change of a fingerprint pattern of a user; and,  
providing input to said computer system according to said detected change of said fingerprint pattern.

2. The method as claimed in claim 1, wherein said change of a fingerprint pattern is a change in width of a fingerprint ridge.

3. The method as claimed in claim 1, wherein said change of a fingerprint pattern is a change of position of said fingerprint pattern.

4. A method of controlling the position of a pointer on a display, which comprises the steps of:

detecting a motion of a fingerprint pattern of a user; and,  
moving said pointer on said display according to detected motion of said fingerprint pattern.

5. The method as claimed in claim 4, wherein:

said step of detecting motion includes the step of detecting the speed of motion of said fingerprint pattern; and,  
said step of moving said pointer includes the step of moving said pointer at a speed proportional to the detected speed of said fingerprint pattern.

6. The method as claimed in claim 4, wherein:

said step of detecting motion includes the step of detecting the direction of motion of said fingerprint pattern; and,  
said step of moving said pointer includes the step of moving said pointer in a direction related to the detected direction of motion of said fingerprint pattern.

7. The method as claimed in claim 4, wherein:

said step of detecting motion includes the step of detecting a change of position of said fingerprint pattern in a first direction and in a second direction orthogonal to said first direction over a selected time interval; and,  
said step of moving said pointer includes the step of moving said pointer on said display in a third direction a distance proportional to said change of position of said fingerprint pattern in said first direction and in a fourth direction orthogonal to said third direction a distance proportional to said change of position of said fingerprint pattern in said second direction.

8. The method as claimed in claim 4, wherein said step of detecting motion of said fingerprint pattern includes the steps of:

capturing successive images of fingerprint ridges and pores; and,

- detecting motion of said ridges and pores based upon said captured successive images.
9. A system for controlling the position of a pointer on a display screen, which comprises:
- means for detecting motion of a fingerprint pattern of a user; and,  
means for moving said pointer on said display according to detected motion of said fingerprint pattern.
10. The system as claimed in claim 9, wherein:
- said means for detecting motion includes means for detecting the speed of motion of said fingerprint pattern; and,  
said means for moving said pointer includes means for moving said pointer at a speed proportional to the detected speed of said fingerprint pattern.
11. The system as claimed in claim 9, wherein:
- said means for detecting motion includes means for detecting the direction of motion of said fingerprint; and,  
said means for moving said pointer includes means for moving said pointer in a direction related to the detected direction of motion of said fingerprint pattern.
12. The method as claimed in claim 9, wherein:
- said means for detecting motion includes means for detecting a change of position of said fingerprint pattern in a first direction and in a second direction orthogonal to said first direction over a selected time interval; and,  
said means for moving said pointer includes means for moving said pointer on said display in a third direction a distance proportional to said change of position of said fingerprint pattern in said first direction and in a fourth direction orthogonal to said third direction a distance proportional to said change of position of said fingerprint pattern in said second direction.
13. The system as claimed in claim 9, wherein said means for detecting motion of said fingerprint pattern includes:
- means for capturing successive images of ridges and pores of a fingerprint; and,  
means for detecting motion of said ridges and pores based upon said captured successive images.
14. A user interface input system, which comprises:
- means for capturing successive images of a surface feature of a digit of a user; and,  
means for detecting a change of said surface feature based upon said captured successive images.
15. The user interface system as claimed in claim 14, wherein said surface feature includes a ridge or a pore of a fingerprint.
16. The user interface system as claimed in claim 14, wherein said change of said surface feature is a change of position of said surface feature.
17. The user interface system as claimed in claim 14, wherein said change of said surface feature is a change of size of said surface feature.
18. The system as claimed in claim 13 or claim 15, wherein said means for capturing successive images includes:
- an array of sensors, each of said sensors being smaller than the width of an individual ridge or pore of a fingerprint.
19. The system as claimed in claim 18, wherein said array is smaller than the pad of a finger of a user.
20. The system as claimed in claim 18 or claim 19, wherein each sensor of said array of sensors includes a capacitive element and said means for capturing successive images includes means for detecting a change in capacitance of a capacitive element.

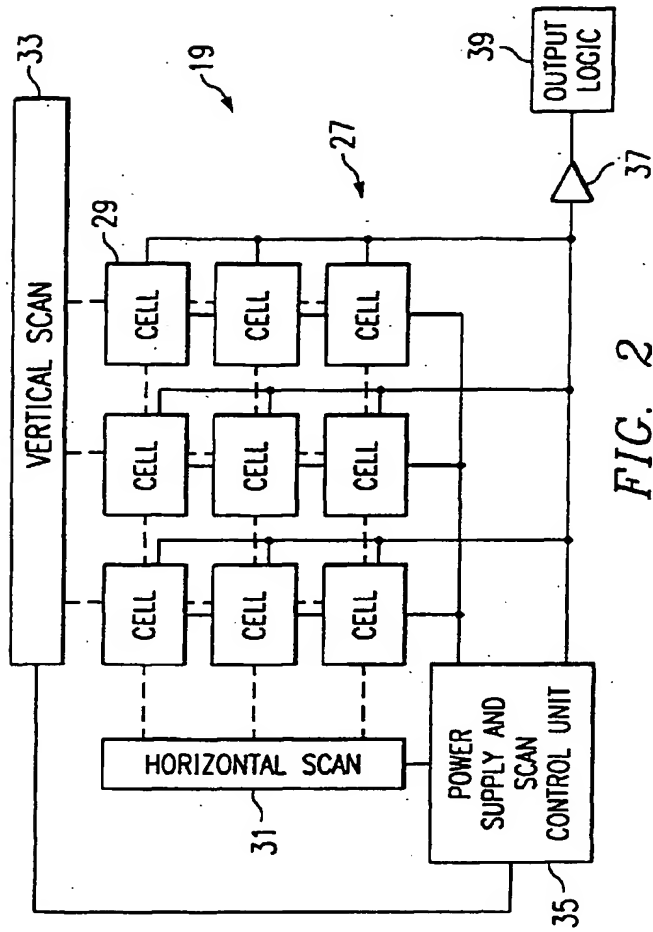


FIG. 2

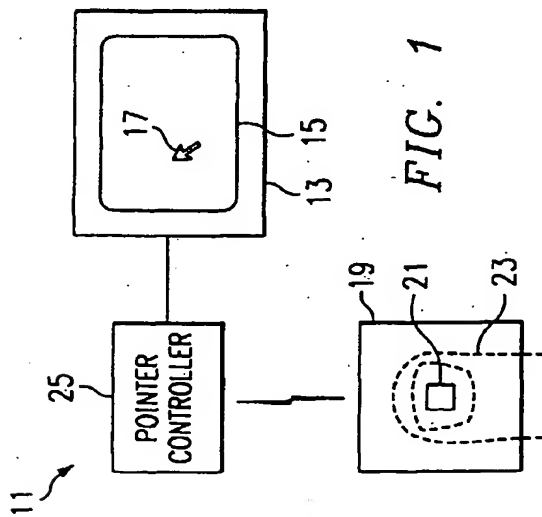


FIG. 1

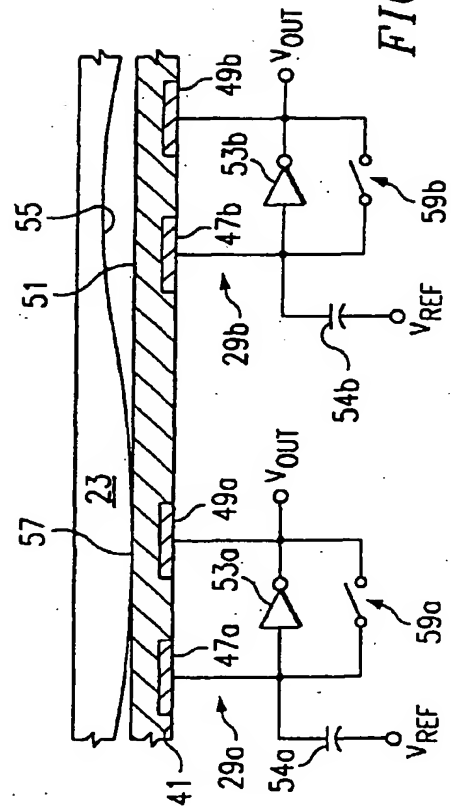


FIG. 3

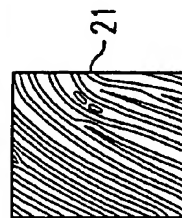
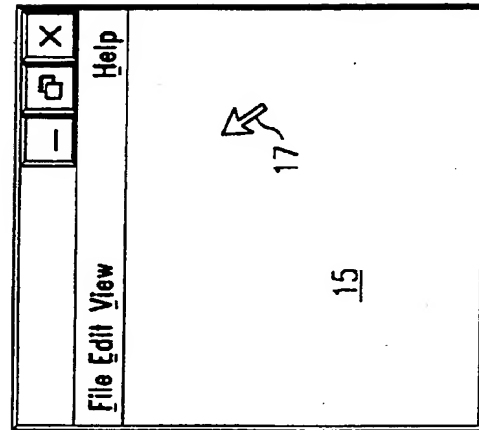


FIG. 4A

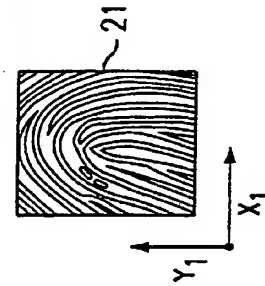
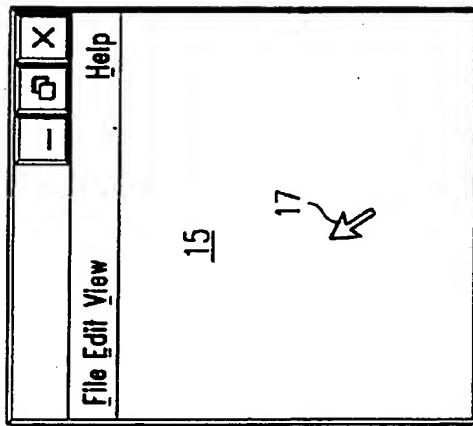


FIG. 4B

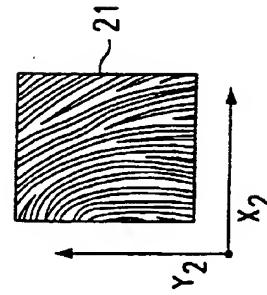


FIG. 4C



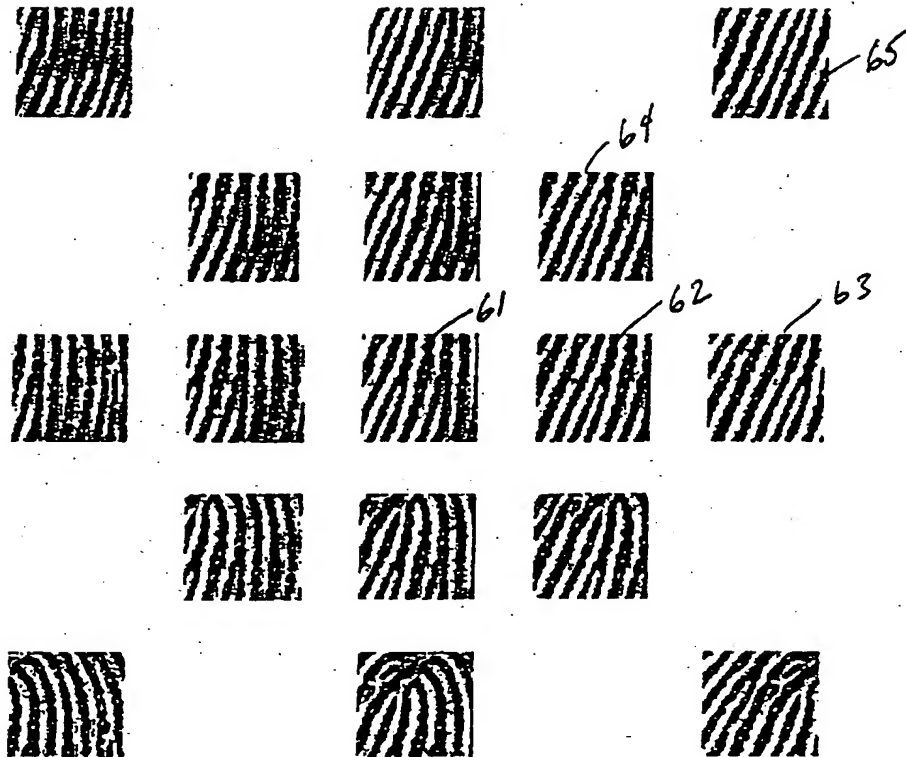


Fig. 4A

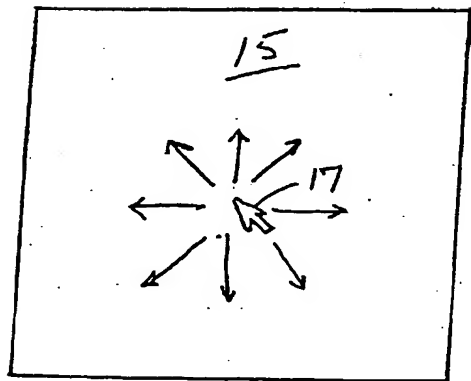


Fig. 4B

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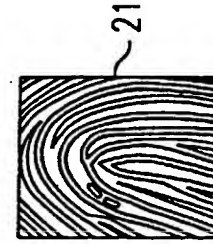
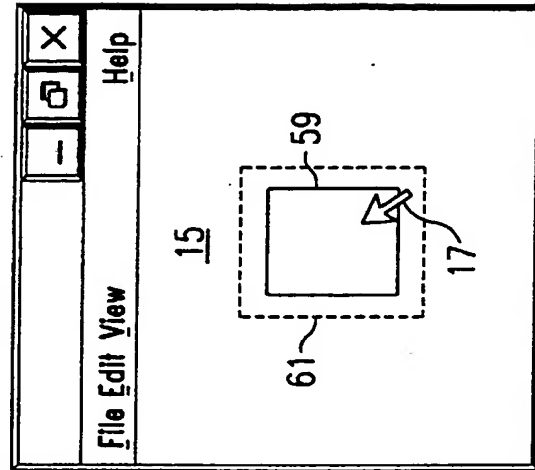


FIG. 5B

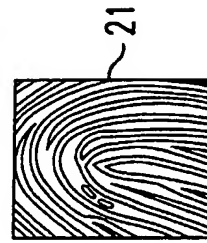
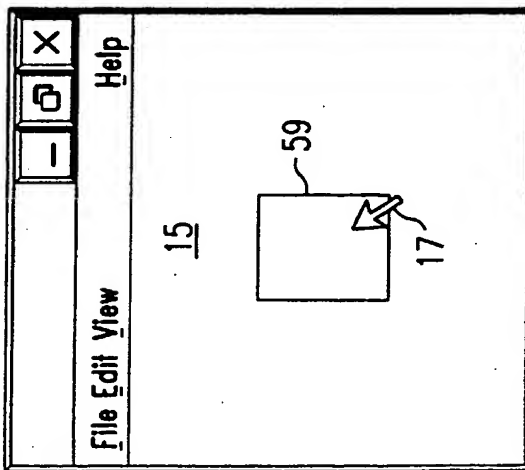


FIG. 5A

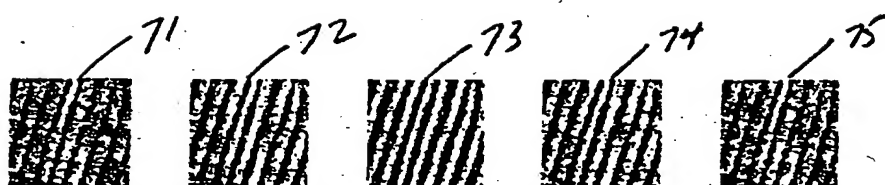


Fig. 5

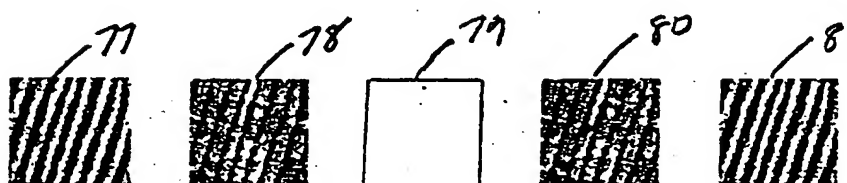
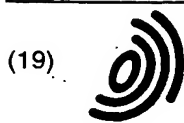


Fig. 6

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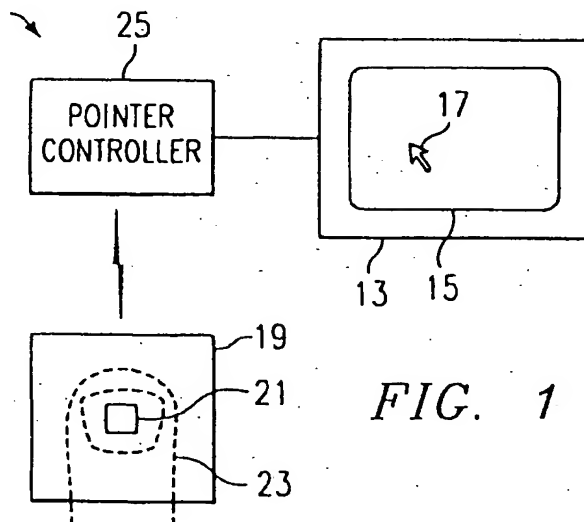
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and moving the pointer on the display according to detected motion of the ridges and pores of the fingerprint. The system captures successive images of the fingerprint ridges and pores and detects motion of the ridges and pores based upon the captured successive images.



**FIG. 1**

**EP 0 929 028 A3**



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 99 30 0188

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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EPO FORM 1503 03/92 (P04C01)



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